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AUTHOR Johnson, Victoria A.
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ABSTRACT

The effectiveness of five methods used to estimate the population parameters of a variable of interest from a random sample in the presence of non-response to mail surveys was tested in conditions that vary the return rate and the relationship of the variable of interest to the likelihood of response. Data from 125,092 adult Alabama residents in the 1980 United States Census were used to simulate the population of interest. Total income was the variable of interest, known only for respondents. Gender and age were the classification variables known for the entire population. From the population, 1,000 random samples were selected and divided into respondents and non-respondents based on 25 different conditions (5 assumptions of response times 5 response rates). The following five methods were used to estimate the population parameter (mean of total income) under each condition: (1) using data from respondents and ignoring non-response; (2) using analysis of waves techniques; (3) using double sampling; (4) weighting; and (5) using hot-deck imputation. Double sampling seems to be the most effective method overall, even though tested under ideal conditions. Ignoring non-response is the least effective method. The study illustrates the importance of determining any relationship between the tendency to respond and the variables of interest. Two tables of data and five graphs illustrate the study. A 54-item list of references is included. (SLD)

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AN ANALYSIS OF METHODS USED TO REDUCE NONRESPONSE BIAS IN SURVEY RESEARCH

by

Victoria A. Johnson

The University of Alabama

Tuscaloosa, Alabama

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INTRODUCTION

The mail survey is one of the major tools that the educational researcher uses to gather data. Aiken (1988) observed that over 50% of all research papers and dissertations in education involve some type of survey. Hartman, Fuqua, and Jenkins (1985) reviewed three scholarly journals in the field of education and found that 69% of the articles published from 1967 to 1978 were based upon survey research. They conducted a similar review of doctoral theses completed in the School of Education at Indiana University between 1976 and 1978 and found that 54% utilized survey methods. A review of doctoral dissertations completed in the School of Education at the University of Alabama from 1984 to 1988 (Jarrell, Johnson, Chissom, & Hughes, 1989) found that 43% relied on a mail survey.

There are many reasons for the popularity of the mail survey. Some of the major advantages frequently cited are the low cost, convenience, possibility for wide geographical distribution, ability to reach people who are difficult to reach, assurance of anonymity, and provision of the opportunity for the respondent to thoughtfully respond (Clausen & Ford, 1947; Edgerton, Britt, & Norman, 1947; Kanuk & Berenson, 1975; Ognibene, 1971).

Unfortunately, there are many potential sources of error in the survey process including: response error; sampling error; imperfections in the design of the survey instrument; errors arising from the timing of the study; processing errors; errors in interpretation (Deming, 1944) and sampling design error (Berty,

1979). Any of these errors can be a serious threat to validity. Much of the study of survey research involves attempts to eliminate or deal with the effects of these errors.

Another source of error inherent in the use of mail surveys arises when some of the members of the sample fail to respond. Statistical inference assumes that the sample upon which the inference is based is random. When certain members in effect withdraw themselves from the sample, can statistical inferences still be made? Under what conditions can they be made? What methods can be used to make them? If they are made, are they valid? How valid? These questions are the focus of this study.

REVIEW OF THE LITERATURE

Researchers have consistently identified the bias due to nonresponse as a major disadvantage of the mail survey (Aiken, 1988; Franzen & Lazarfeld, 1945; Hansen & Hurwitz, 1946; Rogers, Folsom, Kalsbeek, & Clemmer, 1977; Stanton, 1939). Stanton (1939) succinctly stated the problem: "it is difficult to determine the representativeness of the respondents . . . whether those who do reply are representative of those who do not answer the request for information" (p. 96). Kerlinger (1973), insisted that nonresponse bias is so potentially significant a problem that he advises researchers "not to use mail questionnaires if a better method can possibly be used" (p. 441).

Despite Kerlinger's advice, educational researchers continue to use the mail survey as one of the primary methods of data collection. The literature suggests that as people have increasing demands upon their time, they are becoming less willing to

cooperate and respond (American Statistical Association, 1974; Daniel, Shott, Atkins, & Davis, 1982). Therefore, the return rate of surveys has declined, indicating that nonresponse and the potential for nonresponse bias is becoming a greater problem in survey research. Research into the problem of nonresponse bias has focused on one of two directions: elimination or compensation.

One strategy for eliminating the problem of nonresponse bias is the attempt to stimulate response through perfecting the survey instrument and increasing the number of contacts made with the sample member. Various studies have shown that the number of contacts (Clausen & Ford, 1947; Deming, 1953; Fuqua, Hartman, & Brown, 1982; Kanuk & Berenson, 1975), the length and form of the survey instrument (Berty, 1979; Deming, 1944; Norman, 1948), the postage used (Brown & Hartman, 1980; Champion & Sear, 1969; Clausen & Ford, 1947; Heberlein & Baumgartner, 1978), the use of an incentive to respond (Fuqua, et al., 1982; Goodstadt, Chung, Krontiz, & Cook, 1977; Kanuk & Berenson, 1975), the perceived authority of the person requesting the information (Baur, 1947; Norman, 1948, Reuss, 1943), and the inclusion of a personalized cover letter (Bachrack & Scobel, 1967; Fuqua, et al., 1982), all can impact the return rate. The basic goal of this type of research is that, through the perfect design and delivery of the survey instrument, all members of the sample will complete and return the instrument, and the problem will be eliminated. The major problem with this method for dealing with nonresponse bias is that it may not be possible to design the ideal instrument or to complete enough follow-ups to obtain a perfect return rate and, as

long as some member of the sample refuses to respond, the question of validity of inference remains.

A second method employed in attempting to eliminate the problem of nonresponse bias involves the sampling technique. Quota sampling (Sudman, 1966; King, 1983) and substitution sampling (Cornfield, 1942; Houseman, 1953) are two frequently cited. While both of these methods seem to eliminate the problem of nonresponse, neither guarantees a random sample. Inferences based upon them, therefore, may not necessarily be valid.

A third method used to eliminate the problem of nonresponse bias has been to limit the use of the mail survey to those instances where a return rate is likely to be high. This type of research has focused on the determination of the factors that make a person likely to respond to a mail survey. Most previous research has concluded that more educated persons (Suchman & McCandless, 1940), those with more experience with the subject of the survey, those with more and stronger interest in the subject of the survey (Clausen & Ford, 1947; Donald, 1960; Myer & Pratt, 1966; Rollins, 1940), and those with more discretionary time (Clausen & Ford, 1947; Pace, 1939; Stinchcombe, Jones, & Sheatsley, 1981) are more likely to respond. This type of research would ideally lead to a complete definition of the person who would respond to a survey and limit the use of the mail survey to this type of person. The problems inherent in this particular method for dealing with nonresponse are that there is no guarantee that all the factors that determine whether a person will respond can be defined and, if

they could be, it might not be possible to judge whether the members of the population of interest possess them.

A final method in attempting to eliminate the problem of nonresponse bias is to examine the responses to determine if biases in the results can be detected. Some researchers advise that if an adequate return rate is attained (Babbie, 1973; Houseman, 1953; Kerlinger, 1973; Shannon, 1948; The Questionnaire, 1930), the estimate based upon the respondents can be assumed to be unbiased. Others suggest a check of the characteristics of the respondents to determine if they are representative of the sample (Aiken, 1988; Armstrong & Overton, 1977; Boser, 1988; Donald, 1960; Ford & Ziesel, 1949; Reid, 1942; Suchman & McCandless, 1940).

None of these methods for examining the results to determine if biases exist assure that the results are valid. At best, they offer general guidelines to determine if bias does exist.

The other direction research into the problem has taken is in attempting to develop a method to compensate for the bias introduced through nonresponse. The data for the nonrespondents are estimated from the data obtained from the respondents. These estimates of the data for nonrespondents are used to adjust estimates obtained from the respondents to reduce the bias of the estimate.

Two methods of compensation assume that there is a difference in sample members' tendency to respond to the survey. If this tendency is related to the variable of interest, the persons who respond will not be representative of the entire sample in terms of the variable of interest. One method (Analysis of

Waves) assumes that times contacted before responding is an indication of tendency to respond (Armstrong & Overton, 1977; Daniel, 1975; Dunkelberg & Day, 1973; Houseman, 1953; Ognibene, 1971; Zimmer, 1956). A regression line or trend line is fitted to the data assuming that the variable of interest is a function of the cumulative return rate after each contact or wave. The line is then extended to the point where the cumulative return rate would be 100%, and the corresponding estimate of the variable of interest is determined. The second method of compensation that assumes that tendency to respond to the survey is related to the variable of interest, is Double Sampling (Clausen & Ford, 1947; El-Badry, 1956; Fuller, 1974, Rao, 1968). After all the planned contacts are made, a small random sample of the nonrespondents is selected. The responses obtained from this sample are assumed to estimate the responses of all the nonrespondents. These responses from the sample of nonrespondents are weighted in proportion to the total nonrespondents and combined with the responses from the original respondents to estimate the total sample.

The other two methods of compensation assume that the variable of interest is related to characteristics that are known for all members of the sample. When all the contacts are made, the respondents and nonrespondents are grouped according to similar known characteristics. In one method, Weighting (Fuller, 1974; Hartman, et al, 1985; Little, 1986; Mandell, 1974; Mayer & Pratt; 1966), the mean of the variable of interest for each group is weighted by the inverse of the proportion of that group that responded. These weighted means are combined to estimate the

entire sample mean. In the other method, Imputation (Daniel, et al., 1982; Hawlind, 1975), nonrespondents in a group are assigned a value of the variable of interest obtained from a respondent in the same group, either randomly or by some predetermined system. The data obtained from the respondents and the data imputed for the nonrespondents are combined to estimate the entire sample mean. The success of both of these methods depends upon the effectiveness of the grouping mechanism, and there is no simple method for the researcher to use to choose the groups.

METHOD

The purpose of this study was to compare the effectiveness of five methods used to estimate population parameters of a variable of interest from a random sample in the presence of nonresponse. The methods were tested in conditions varying the return rate and the relationship of the variable of interest to the likelihood of response.

Data obtained from 125,092 adult Alabama residents in the 1980 U.S. Census were used to simulate the population of interest. Total Income was used as the variable of interest and assumed to be known only for the respondents. Gender and Age, which are known to relate to Total Income, were used as classification variables and assumed to be known for the entire population. Two of the methods used these variables in estimating the population parameter. Additionally, another variable was generated from a normal distribution. This variable was used to simulate the sample member's tendency to respond to the survey. This distribution was assigned to the members of the population five different times,

each assignment reflecting a stronger relationship between probability of responding to the survey and Total Income (the variable of interest).

The first assignment (Response 1) was to assign the distribution randomly to the population. This simulated the assumption that tendency to respond is a normally distributed random variable. The correlation between Response 1 and Total Income was Very Low (r = .001).

The second assignment (Response 2) was to assign the distribution based upon education. The correlation between Response 2 and Total Income was Low (r = .328). Response 2 simulated the assumption that the correlation between tendency to respond and the variable of interest is Low.

The third assignment (Response 3) was to assign the distribution based upon hours worked per week in the previous year. The correlation between Response 3 and Total Income was Moderate (r = .479). Response 3 simulated the assumption that the correlation between tendency to respond and the variable of interest is Moderate.

The fourth assignment (Response 4) was to assign the distribution based upon earned income. The correlation between Response 4 and Total Income was High (r = .714). Response 4 simulated the assumption that the correlation between tendency to respond and the variable of interest is High.

The final assignment (Response 5) was based upon Total Income. Estimating population parameters is most difficult when the tendency to respond is directly related to the variable of

interest because, under this condition, the difference between the respondents and nonrespondents is the greatest. This variable simulated that relationship. The correlation between Response 5 and Total Income was Very High (r = .874).

These response variables were used to divide the sample into respondents and nonrespondents. Those with the h .est values for the tendency to respond variable were considered to be respondents and the rest were nonrespondents.

From the population, 1000 random samples (n = 500) were selected. Five different return rates, corresponding to the various minimum acceptable rates suggested by the literature were simulated. These were: Rate 1 = 50% (The Questionnaire, 1930), Rate 2 = .60% (Babbie, 1973), Rate 3 =70% (Shannon, 1948), Rate 4 = 80% (Kerlinger, 1973) and Rate 5 = 90% (Houseman, 1953).

Each sample was divided into respondents and nonrespondents 25 different ways, based upon the 25 different conditions (five Assumptions of Response X five Response rates). Five different methods were used to estimate the population parameter (mean of Total Income) under each condition.

Method 1 ignored the nonresponse and estimated mean Total Income using data obtained from the respondents. This simulated the situation where the researcher believes that there is no difference between respondents and nonrespondents, either because the return rate is adequate or checks for bias have indicated that there is none.

Method 2 used Analysis of Waves. For each condition, all respondents were divided into three groups or waves: (1) the top

60% in terms of highest probability of responding, (2) the next 25%, and (3) the lowest 15%. These percentages approximate the average of those reported in several studies (Filion, 1976a; Toops, 1926; Zimmer, 1956). A regression equation was fitted to the data using mean Total Income as the dependent variable, and cumulative return as the predictor variable. The regression equation was then used to estimate the value of mean Total Income when the predictor variable (cumulative return rate) equaled 100.

Method 3 used Double Sampling. For each condition, most respondents were selected based upon the appropriate response variable (Response 1 - Response 5) and 10% of the nonrespondents were selected randomly. The mean Total Income of the 10% was weighted by the total number of nonrespondents and combined with the mean Total Income of the original nonrespondents to estimate the mean Total Income.

Method 4 used Weighting. The population was divided into four groups based upon gender and age, maximizing the difference in mean Total Income among groups. Group 1 (n=26,378) consisted of males under 30 or over 60 years of age. Group 1 had a mean Total Income of $9308. Group 2 ($n$=31,588) consisted of males between 30 and 60 years of age. Group 2 had a mean Total Income of $16,405. Group 3 ($n$=32,288) consisted of females under 30 or over 60 years of age. Group 3 had a mean Total Income of $4314. Group 4 ($n$=34,838) consisted of females between 30 and 60 years of age. Group 4 had a mean Total Income of $5133. For each sample, the respondents and nonrespondents were grouped according to gender and age. The mean of each group was weighted by the inverse of the

return rate for each group, and combined to estimate mean Total Income.

Method 5 used Hot-Deck Imputation. For each condition, the respondents and nonrespondents were grouped according to gender and age, using the same grouping as Method 4. The nonrespondents were randomly assigned one of the values of Total Income obtained from a respondent from the same group. The Total Income of the respondents and the imputed Total Income of the nonrespondents were combined to estimate mean Total Income.

The nonresponse bias of each estimate was determined by finding the absolute value of the difference between the actual mean Total Income for the sample and the estimated mean Total Income for the sample. The bias of the estimate was used as a measure of the effectiveness of the method of estimation, i.e the smaller the bias the more effective the method.

RESULTS

Analysis of variance was used to test the significance of the effects model. Table 1 presents the summary of that analysis.

Table 1 ANOVA Summary for Effects Model

Source	SS	DF	M	F
Model	349521680851	1123	311239253	2053*
Method*Rate*Response	7488110798	64	117001731	772*
Method*Rate	18650624700	16	1165664044	7691*
Method*Response	48471635742	16	3029477234	19987*
Rate*Response	16555993878	16	1034759617	6827*
Method	68989190596	4	1724727649	113791*
Rate	42715270521	4	1067881763	7045*
Response	143902413262	4	3597560330	23735*
Sample	2748441352	999	2751193	18*
Error	18775885854	123876	151570	

* $p < .05$

As Table 1 indicates, the model was statistically significant. Also, the three-way interaction effect was significant, indicating that the effectiveness of the methods used to reduce nonresponse bias varies among the levels of relationships between tendency to respond and Total Income at each level of return.

Table 2 presents the mean response bias of the estimate for each method of analysis, at each level of relationship between tendency to respond and Total Income, at each return rate. Each cell represents the mean nonresponse bias (the absolute value of the difference between the estimated mean Total Income and the actual mean Total Income for the sample) for the particular combination of method, level, and rate. Figure 1 through Figure 5 present the same information in graphic form.

The graphs clearly illustrate the interaction effect of method, assumptions of response, and return rate. Simple simple effects were analyzed and the results are reported in full in Johnson (1990). Interpretation of the results focused on practical differences rather than on statistically significant differences.

Double Sampling was found to be the method least influenced by the degree of relationship between tendency to respond and the variable of interest, and its effectiveness actually increased as the return rate decreased. This finding indicates that Double Sampling has the greatest potential among the five methods tested to compensate for nonresponse bias.

Wave Analysis was found to be the least predictable of the five methods tested. It was generally less effective as the relationship between tendency to respond and the variable of

TABLE 2

Mean bias of estimate for each method of analysis at each level of Relationship between tendency to respond and Total Income at each rate of return

Return Rate 90% Return	Double Sampling	Wave Analysis	Weighting	Imputation	Ignore NR
Relationship					
Very Low	819	169	103	141	119
Low	872	534	729	733	839
Moderate	843	213	634	638	1029
High	801	1576	1827	1832	2185
Very High	783	1535	2144	2146	2457

Return Rate 80% Return	Double Sampling	Wave Analysis	Weighting	Imputation	Ignore NR
Relationship					
Very Low	694	291	155	205	174
Low	839	626	1159	1161	1330
Moderate	815	436	1503	1497	2074
High	724	2425	2910	2916	3384
Very High	752	2051	3460	3461	3807

Return Rate 70% Return	Double Sampling	Wave Analysis	Weighting	Imputation	Ignore NR
Relationship					
Very Low	605	458	204	271	229
Low	752	543	1488	1484	1673
Moderate	697	707	2236	2244	2915
High	609	3510	3693	3699	4254
Very High	652	2471	4580	4579	4875

Return Rate 60% Return	Double Sampling	Wave Analysis	Weighting	Imputation	Ignore NR
Relationship					
Very Low	494	716	257	324	289
Low	683	687	1739	1749	1924
Moderate	613	1641	3101	3113	3875
High	552	3431	4192	4205	4865
Very High	544	2899	5568	5565	5787

Return Rate 50% Return	Double Sampling	Wave Analysis	Weighting	Imputation	Ignore NR
Relationship					
Very Low	328	1143	322	384	360
Low	512	983	2194	2203	2375
Moderate	456	3055	3941	3940	4688
High	393	2681	4379	4378	5185
Very High	429	3370	6446	6445	6896

Figure 1

MEAN BIAS OF ESTIMATE FOR EACH METHOD OF ANALYSIS

FOR EACH LEVEL OF RELATIONSHIP BETWEEN TENDENCY TO RESPOND AND TOTAL INCOME
RETURN RATE=90%

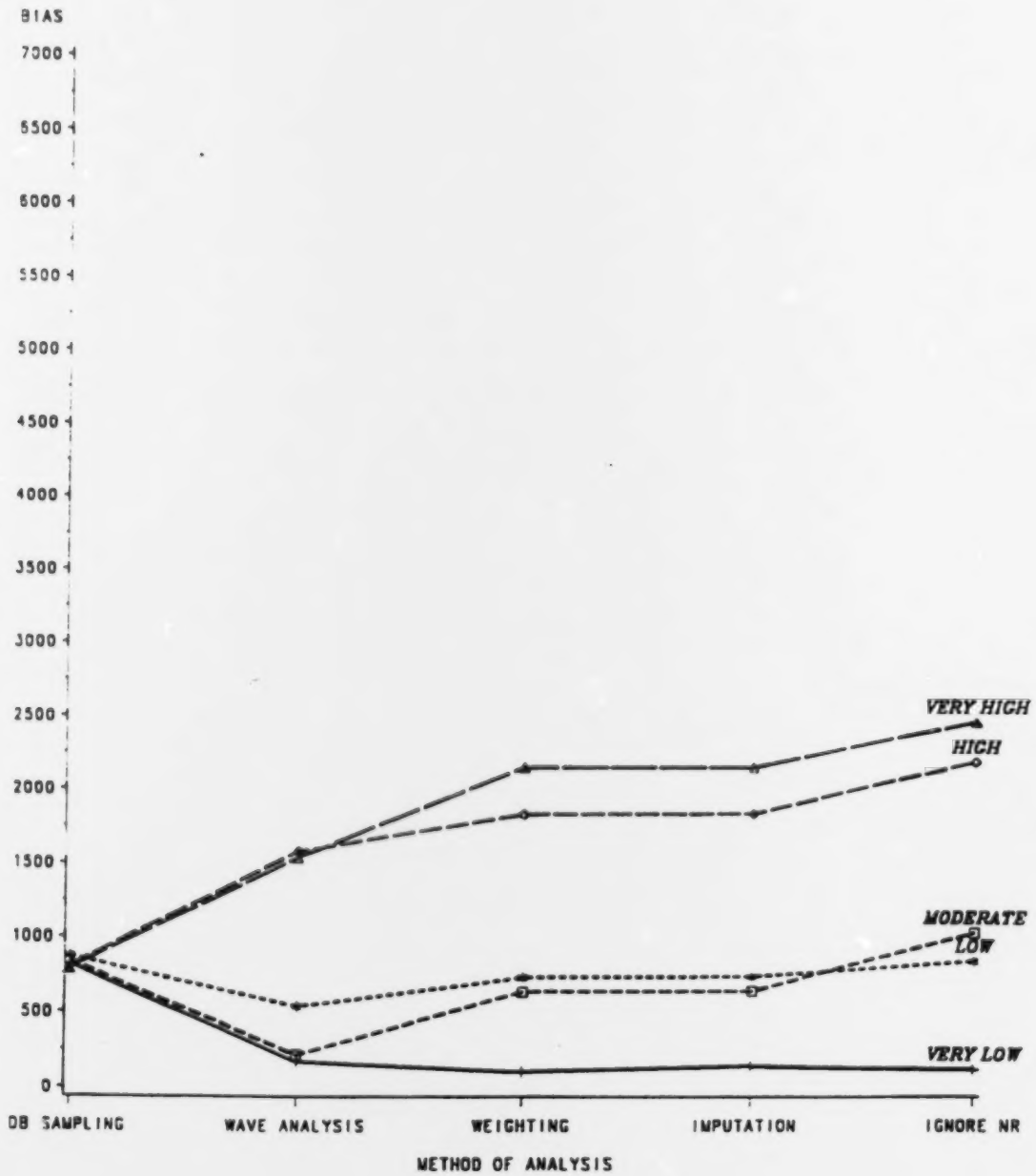


Figure 2

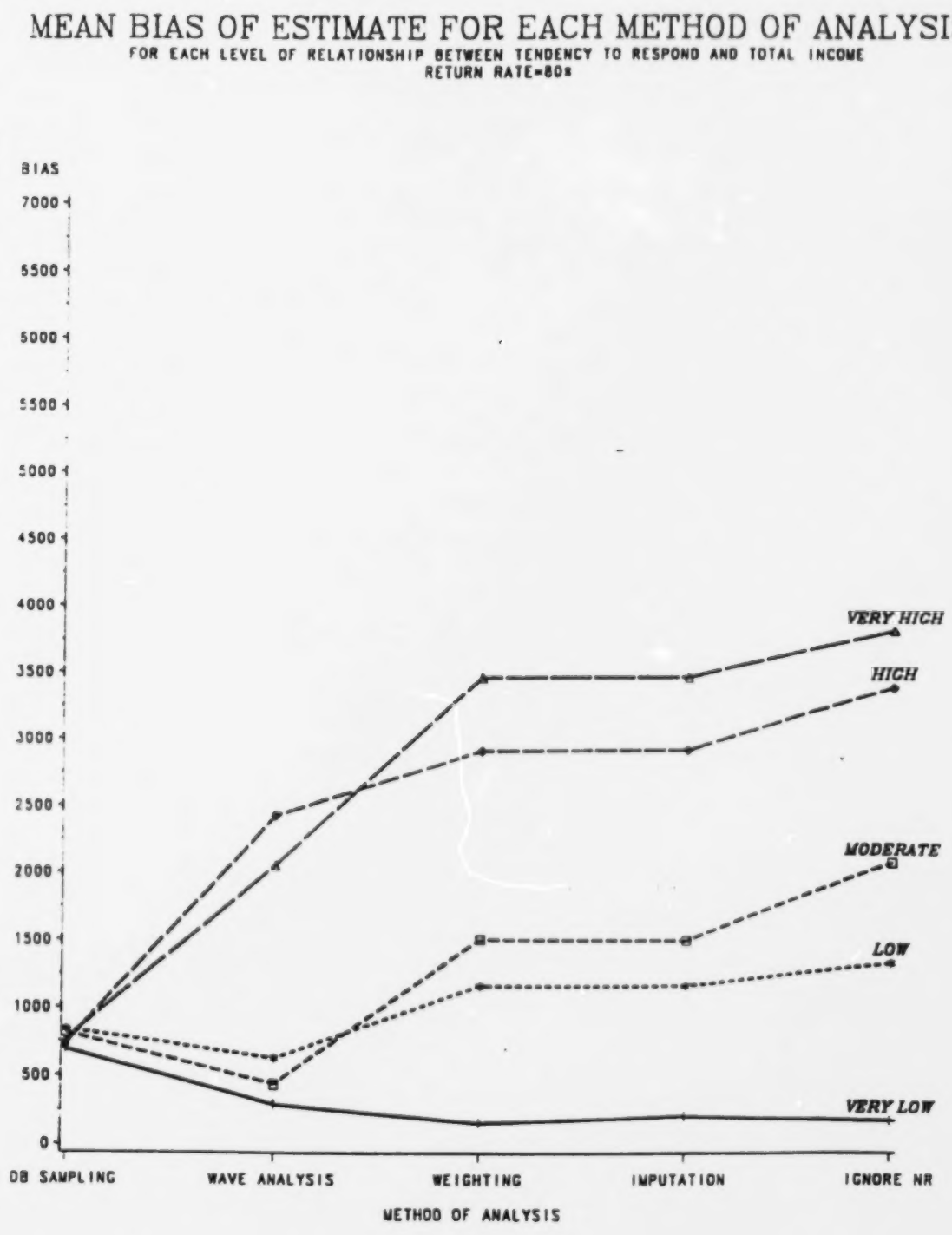

MEAN BIAS OF ESTIMATE FOR EACH METHOD OF ANALYSIS
FOR EACH LEVEL OF RELATIONSHIP BETWEEN TENDENCY TO RESPOND AND TOTAL INCOME
RETURN RATE=80%
BIAS
7000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
VERY HIGH
HIGH
MODERATE
LOW
VERY LOW
DB SAMPLING
WAVE ANALYSIS
WEIGHTING
IMPUTATION
IGNORE NR
METHOD OF ANALYSIS

Figure 3

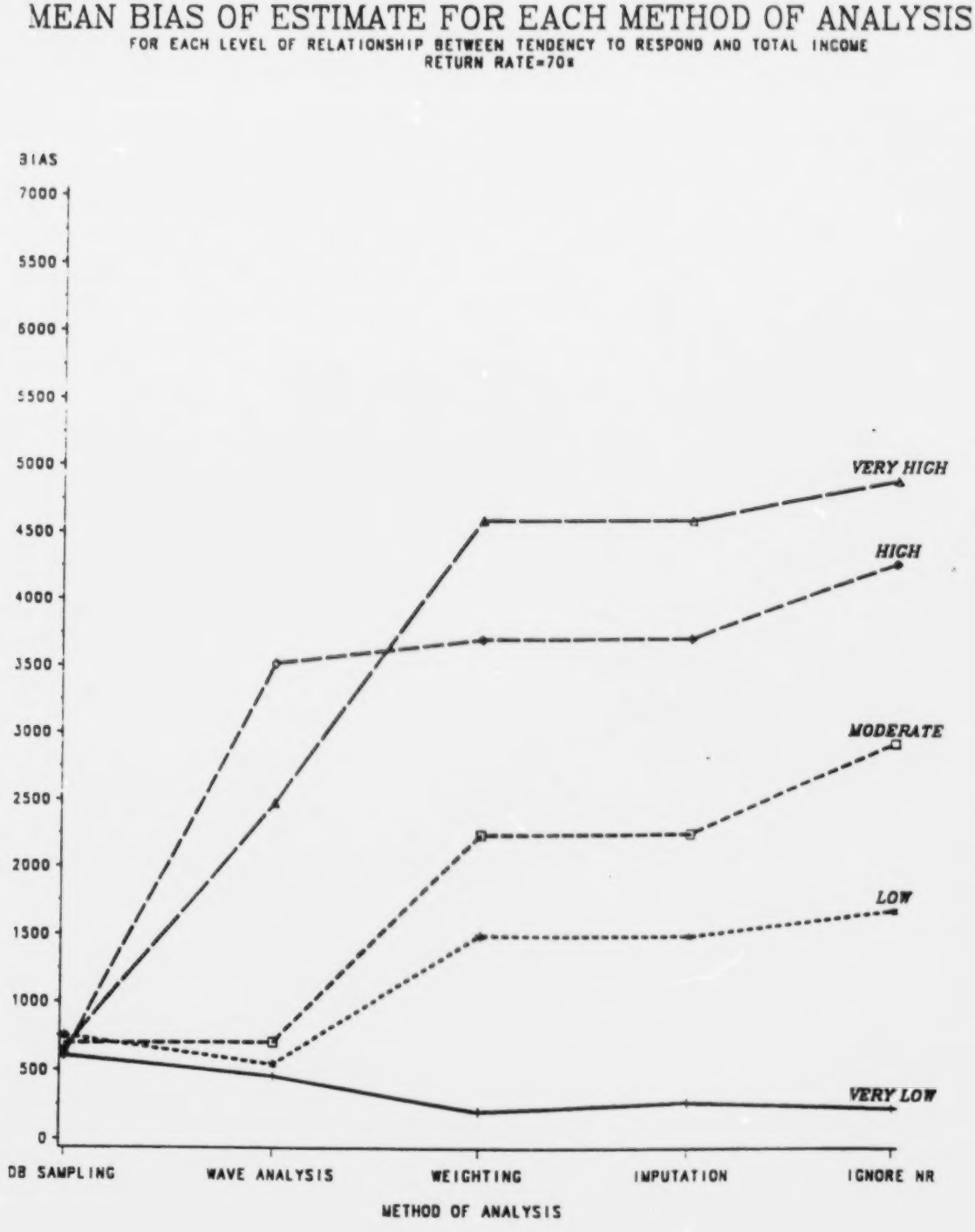

MEAN BIAS OF ESTIMATE FOR EACH METHOD OF ANALYSIS
FOR EACH LEVEL OF RELATIONSHIP BETWEEN TENDENCY TO RESPOND AND TOTAL INCOME
RETURN RATE=70%
BIAS
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
VERY HIGH
HIGH
MODERATE
LOW
VERY LOW
DB SAMPLING
WAVE ANALYSIS
WEIGHTING
IMPUTATION
IGNORE NR
METHOD OF ANALYSIS

Figure 4

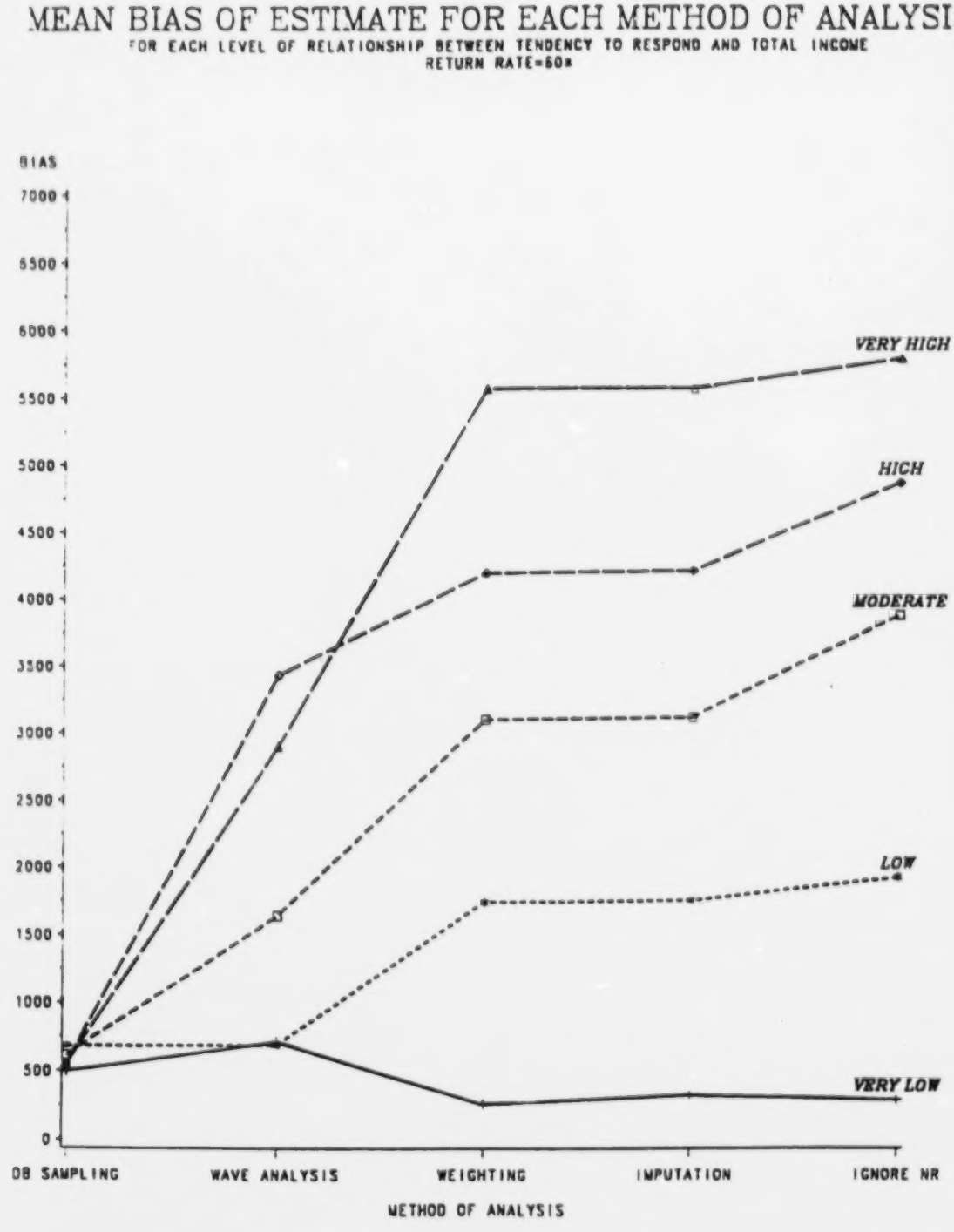
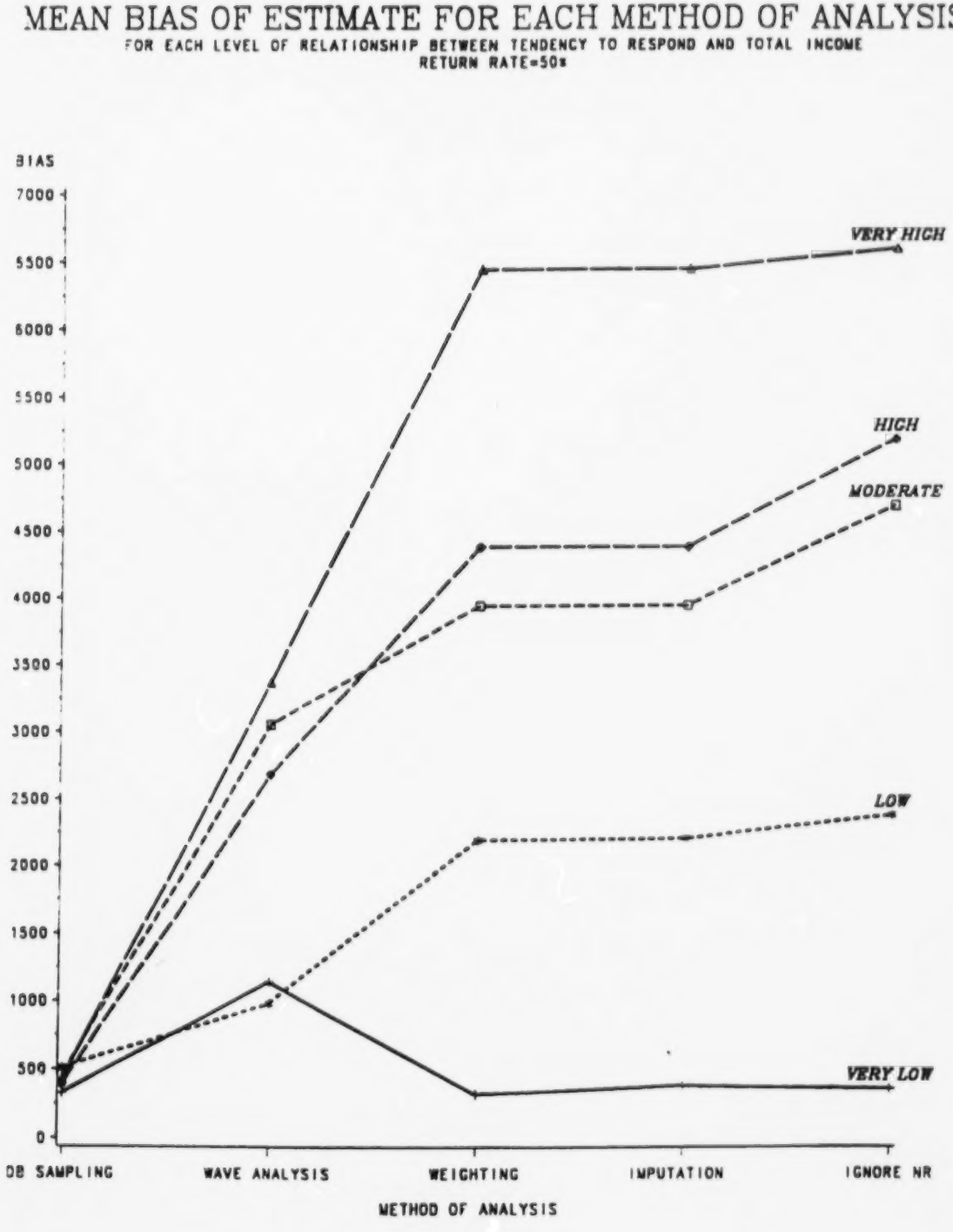

MEAN BIAS OF ESTIMATE FOR EACH METHOD OF ANALYSIS
FOR EACH LEVEL OF RELATIONSHIP BETWEEN TENDENCY TO RESPOND AND TOTAL INCOME
RETURN RATE=60%
BIAS
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
VERY HIGH
HIGH
MODERATE
LOW
VERY LOW
OB SAMPLING
WAVE ANALYSIS
WEIGHTING
IMPUTATION
IGNORE NR
METHOD OF ANALYSIS

Figure 5


MEAN BIAS OF ESTIMATE FOR EACH METHOD OF ANALYSIS
FOR EACH LEVEL OF RELATIONSHIP BETWEEN TENDENCY TO RESPOND AND TOTAL INCOME
RETURN RATE=50%
BIAS
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
VERY HIGH
HIGH
MODERATE
LOW
VERY LOW
DB SAMPLING
WAVE ANALYSIS
WEIGHTING
IMPUTATION
IGNORE NR
METHOD OF ANALYSIS

interest increased, but at every return rate there was at least one combination where the trend reversed. However, when there was at least a low relationship between tendency to respond and the variable of interest, Wave Analysis was more effective than Weighting, Imputation, and Ignoring Nonresponse, regardless of the return rate. This finding indicates that Wave Analysis may be the superior method of analysis under those conditions.

This study found no differences between Weighting and Imputation at any level of relationship between tendency to respond and the variable of interest at any return rate. Both methods were effective only when there was a Very Low relationship. The bias of the estimate increased very rapidly as both the level of relationship and return rate increased. This study indicates that Weighting and Imputation are not effective at reducing nonresponse bias but are better than Ignoring Nonresponse, especially as the level of relationship increased and the return rate decreased.

Although Ignoring Nonresponse is the most common "method" used, according to the literature, the findings of this study indicate that it was the least effective, especially at low return rates and high levels of relationship between tendency to respond and the variable of interest.

DISCUSSION

This study illustrates the effect of the relationship between tendency to respond and the variable of interest on nonresponse bias. Although Double Sampling seems to be the most effective method overall, this study tested it under ideal conditions. Not only was the response obtained from the total sample of non-

respondents, the study assumed no response error. Both of these conditions generally do not occur in survey research, and their effect must be determined. Wave Analysis was also implemented under the assumption that those with a higher tendency to respond will respond earlier than those with the lower tendency. This assumption may not always be warranted. Weighting and Imputation were not found to be especially effective in this study. One problem with these methods is that their effectiveness is generally assumed to depend upon the groupings used. Although this study used more knowledge than the survey researcher would have (knowledge of the variable of interest for the entire population) to make the groupings, it could be argued that these were not the most effective groupings possible, and a different set of groups would have produced different results. Finally, these results clearly show the ineffectiveness of totally Ignoring Nonresponse.

The most important need suggested by this study is to evaluate methods used to detect the relationship between tendency to respond and the variable of interest. It has shown that methods used to compensate for nonresponse bias vary in effectiveness depending on both that relationship and the return rate. The researcher can easily calculate the return rate, but determining the relationship is more difficult. This study illustrates how important it is for the researcher to determine if there is any relationship between the tendency respond and the variable of interest. Unless there is a Very Low relationship, the bias of the estimate can be large, regardless of the method of analysis, especially if the return rate is low.

There are several methods suggested to determine the relationship, but their effectiveness has not been evaluated. A comprehensive study is needed to evaluate these methods or to suggest more effective methods that researchers can use to determine the level of the relationship between the tendency to respond and the variable of interest for their particular survey. Only then will researchers be assured that the method used will be the most effective in reducing nonresponse bias.

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